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RESPONSE OF POLE-SIZE LODGEPOLE PINE TO FERTILIZATION

by

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ABSTRACT

Large, significant increases in annual volume, basal area, and bole area growth, as well as grass production in the understory, were obtained during a 4-year period after application of N, P, and S. Measurements of annual radial wood growth indicate that these favorable responses will last longer than 4 years. Height growth and soil water use were not increased significantly by fertilization, but sampling error may have masked real differences in water use.

KEYWORDS: Fertilizer response (forest tree), lodgepole pine, Pinus contorta.

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INTRODUCTION

Thinning is the most practical method of increasing usable wood production of lodgepole pine (*Pinus contorta* Dougl.) stands in south-central Oregon (Dahms 1971). The possibility of further increases in production of usable wood through thinning plus fertilization is of interest for future timber management planning. Increased growth of lodgepole pine seedlings in growth chambers after nitrogen (N), phosphorus (P), and sulfur (S) fertilization has been reported (Cochran 1972); but I know of only one published result concerning fertilization of lodgepole pine in the field in North America. Linteau (1962) reported on application of magnesium oxide and potassium chloride at rates of 50 and 100 pounds per acre, respectively, both alone and in combination to a 4-year-old lodgepole pine plantation in Quebec. After the second growing season, the double treatment produced significant increases in growth over other treatments. Also "Mg-treated plots were better than K-treated, and K-treated were better than control." Lodgepole pine has been planted on peats in Great Britian and Norway where responses to phosphorus (Neustein 1962, Lines 1968), to nitrogen and phosphorus (Dickson 1965), and to potassium, phosphorus, and nitrogen (Baldwin 1967, Meshechok 1967) have been recorded.

METHODS OF STUDY

In a preliminary greenhouse experiment, lodgepole pine seedlings grown on soil material from a Lapine AC horizon responded favorably to additions of nitrogen, phosphorus, and sulfur, but boron (B) reduced growth over the ranges and combinations of elements tested.[1/] Maximum seedling response in the incomplete factorial experiments was equivalent to additions of N, P, and S of 600, 300, and 90 pounds per acre,[2/] respectively. Although these amounts seem high for field application, I decided to see how these rates would influence growth of larger trees in the field.

Ten 1/10-acre plots (1- by 1-chain) surrounded by a buffer strip one-half chain wide were established in a pole-size stand located on the Chemult District of the Winema National Forest (section 13 of R. 9 E., T. 28 S. and section 18 of R. 10 E., T. 28 S.). Elevation of the study area is about 5,300 feet. Precipitation averages 26.6 inches per year in Chemult, 11 airline miles west of the stand; and summers are very dry (Franklin and Dyrness 1973). The plots are on a north by northwest aspect, and slopes are less than 5 percent. The understory community is antelope bitterbrush (*Purshia tridentata*)/western needlegrass (*Stipa occidentalis*). The stand, which was established after a fire, lies directly adjacent to an upslope stand of ponderosa pine (*Pinus ponderosa* Laws.) and white fir (*Abies concolor* (Gord. & Glend.) Lindl.) with a snowbrush (*Ceanothus velutinus*) understory. The Lapine soil, a Typic Cryorthent, developed on deep pumice; it has A1, AC, C1, and C2 horizons (table 1). Roots are concentrated in the A1 and AC horizons. The stand was thinned in the winter of 1966-67 when it was about 40 years old.

Table 1.--*Some properties of the Lapine soil at the study site*[1/]

Horizon	Depth	pH	P	B	Extractable cations				Total N	O.M.[2/]	S	C.E.C.[3/]
					K	Ca	Mg	Na				
	Inches		- p/m -		- - - meq/100 g - - -				- - Percent - -		p/m	meq/100 g
A1	0-2	6.2	7	0.33	124	3.0	0.20	0.50	0.13	17.8	2.8	12.6
AC	2-19	6.5	5	.45	72	2.1	.20	.81	.05	.29	2.7	8.1
C1	19-37	6.6	3	.16	48	.6	.16	.37	.01	.77	.8	4.6
C2	37-72	6.5	3	.23	44	.7	.20	.17	.005	.10	.6	4.6

[1/] Analyses were performed by the Oregon State University soil testing laboratory, Corvallis, by its methods (Roberts et al. 1971).

[2/] O.M. = organic matter.

[3/] C.E.C. = cation exchange capacity.

[1/] Data from this experiment were lost in a fire which destroyed the Silviculture Laboratory in Bend, Oregon, on January 15, 1974.

[2/] Metric unit conversion factors are listed at end of text.

Five of the plots were randomly chosen for fertilization. S was applied as ammonium sulfate (21-0-0, 24-percent S), additional N was added as urea (45-0-0), and P was applied as treble superphosphate (0-45-0) in late October 1970. Every tree in each plot was measured with a Barr and Stroud optical dendrometer.[3/] These dendrometer measurements were subjected to an STX-Fortran-4 program (Grosenbaugh 1967) to calculate the initial stand parameters shown in table 2. Table 2 does not include one tree lost to snow breakage the first winter after plot establishment or four trees accidentally destroyed when the thinning slash was tomahawked[4/] 2 years after plot establishment.

Table 2.--*Some initial stand parameters for fertilized and control plots*

Plot number	Basal area	Bole area[1/]	Volume[1/]	Average height	Average diameter[2/]	Trees per acre
	Square feet per acre		Cubic feet per acre	Feet	Inches	Number
Fertilized:						
9	14.6	2,266	204	26.7	4.9	100
7	21.4	4,175	374	36.0	5.4	130
10	30.3	4,705	486	36.2	6.4	130
5	35.7	6,745	601	36.0	5.5	210
1	42.4	7,329	790	42.0	6.9	160
Control:						
6	16.6	3,140	229	26.7	4.1	170
8	31.2	5,333	509	34.6	5.7	160
4	37.7	5,958	619	36.2	6.5	160
3	38.4	6,868	708	39.6	6.3	170
2	51.1	9,275	966	40.5	6.5	220

1/ Values do not include bole areas and volumes of 1-foot stumps.

2/ This diameter is the actual mean diameter and is not the diameter derived from the average basal area.

Grass production was determined by clipping three 2- by 12-foot transects randomly located on each plot in late summer. Brush production was not determined because trial sampling indicated that the variation in brush production between individual transects was so large that the entire plot would have to be clipped for an adequate sample. Besides needlegrass, bottlebrush squirreltail grass (*Sitanion hystrix*) was found in the plots.

Soil water use down to 5-foot depth was estimated during the 1974 growing season with a neutron probe. Three access tubes were placed in each plot. Each tube was located in the center of a tree opening having a diameter equivalent to the average tree spacing within the plot. Soil water contents were

3/ Mention of companies or products by name does not constitute an endorsement by the U.S. Department of Agriculture.

4/ Tomahawking is a method for reducing fire hazard in slash by mechanical crushing with an implement called a "Tomahawk" mounted on the front of a crawler tractor (Dell and Ward 1969).

first measured on May 28 right after the late snowmelt, and the last measurements were taken on October 1, 1974, before the fall rains started.

Four growing seasons after treatment every tree in each plot was again measured with an optical dendrometer (table 3). These measurements were compared with initial measurements (table 2) to determine annual growth rates for the 4-year period. Annual growth rates were then subjected to analysis of covariance (with initial basal area as the covariate) to determine if growth rates were increased by fertilization. To test treatment effects on grass production and water use, t-tests were used after initial analysis showed that these factors did not vary with stand basal area or any other measured variable except treatment.

Table 3.--*Some stand parameters for fertilized and control plots four growing seasons after beginning of study*

Plot number	Basal area	Bole area[1/]	Volume[1/]	Average height	Average diameter[2/]	Trees per acre
	- - Square feet per acre - -		Cubic feet per acre	Feet	Inches	Number
Fertilized:						
9	21.9	2,935	322	27.9	6.1	100
7	32.2	5,394	582	38.6	6.5	130
10	38.6	5,717	667	38.3	7.2	130
5	50.9	8,662	908	38.9	6.6	210
1	54.5	8,944	1,091	45.9	7.9	160
Control:						
6	21.9	3,690	291	28.1	4.7	170
8	35.5	6,156	637	37.2	6.5	160
4	43.9	6,792	762	38.1	7.0	160
3	45.4	7,805	863	41.4	6.9	170
2	58.2	10,432	1,136	42.5	6.9	220

1/ Values do not include bole areas and volumes of 1-foot stumps.

2/ This diameter is the actual mean diameter and is not the diameter derived from the average basal area.

Patterns of radial wood growth and needle length changes were determined at the end of the fourth growing season from increment borings at 4.5 feet and from measurements of needle lengths on branches which could be reached from the ground where distinct years of development could be determined. These measurements were made on trees in the buffer strips of single control and fertilized plots having the highest initial basal areas. Measurements were made on 10 trees for the fertilized plot and 5 trees for the nonfertilized plot; t-tests were used to assess influence of fertilization on radial growth and needle length.

RESULTS

Regression lines relating annual growth of volume, bole area, and basal area to initial basal area were significantly higher for fertilized plots (figs. 1, 2, and 3 and table 4). However, average height growth for the fertilized trees, 0.6 foot per year, was not significantly greater than the 0.5 foot per year average for the nonfertilized trees (table 4).

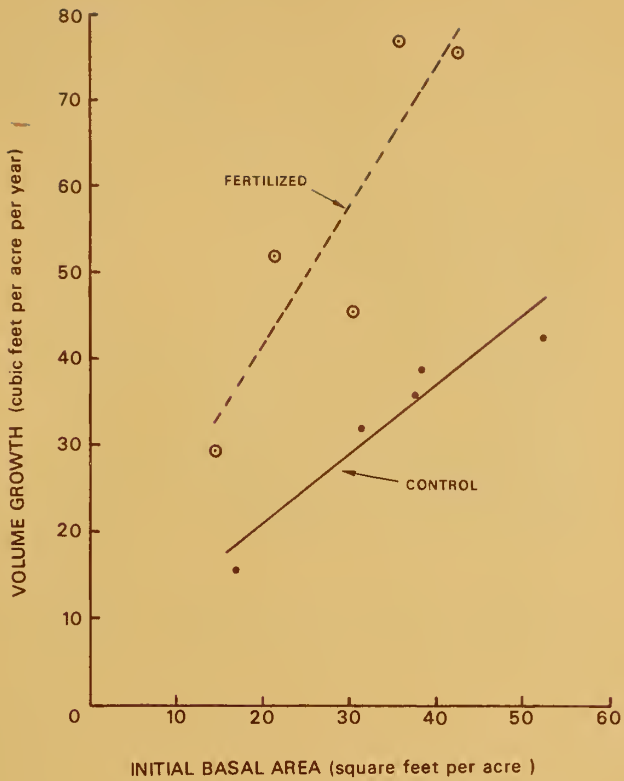

Figure 1.--Annual volume growth as a function of initial basal area. Differences in growth between fertilized and control plots are significant at the 1-percent level of probability. Straight lines represent calculated regressions accounting for 79 percent (fertilized) and 92 percent (control) of the variation in growth.

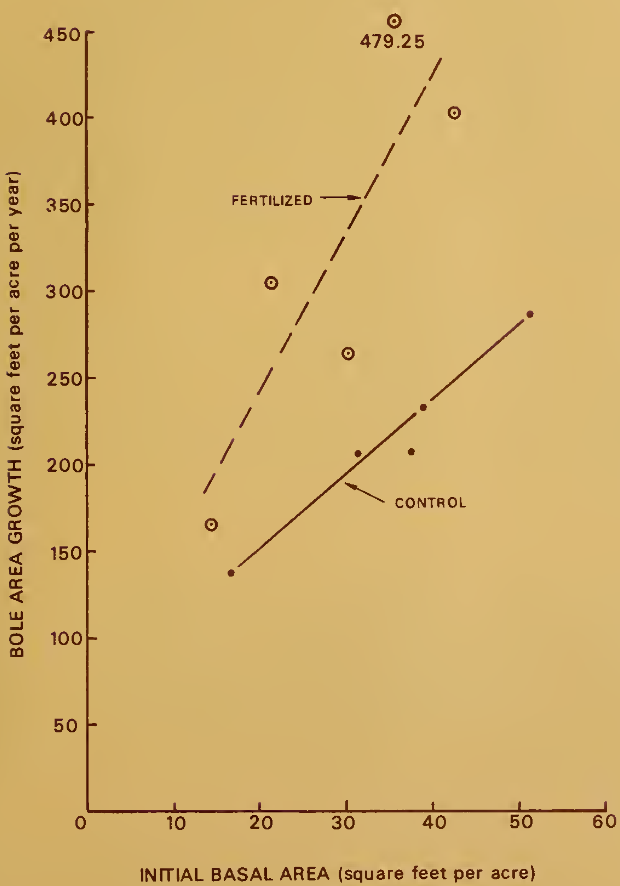

Figure 2.--Annual bole area growth as a function of initial basal area. Differences in growth between fertilized and control plots are significant at the 5-percent level of probability. Straight lines represent calculated regressions accounting for 66 percent (fertilized) and 96 percent (control) of the variation in growth.

Figure 3.--Annual basal area growth as a function of initial basal area. Differences in growth between fertilized and control plots are significant at the 5-percent levelof probability. Straight lines represent calculated regressions accounting for 46 percent (fertilized) and 47 percent (control) of the variation in growth.

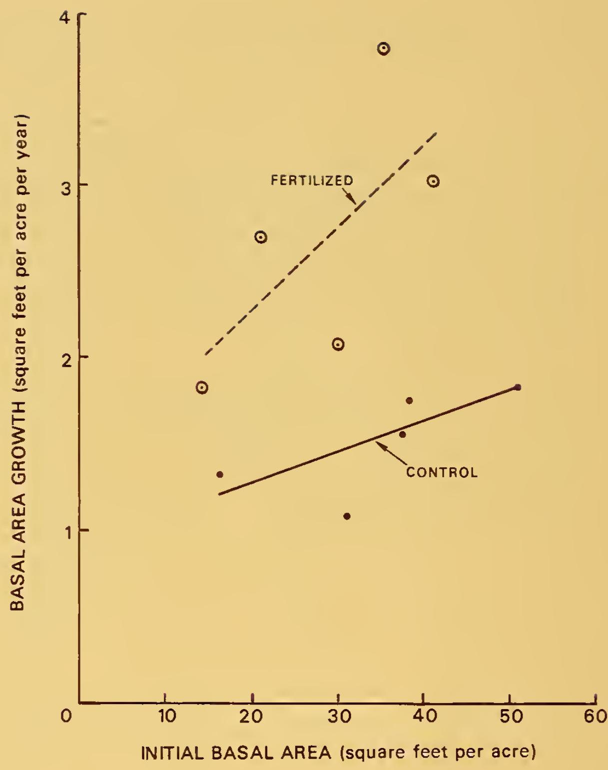

Table 4.--*Annual basal area, bole area, volume, and height growth during four growing seasons*

Plot number	Basal area	Growth per acre per year of bole area[1]	Volume	Average height growth per year per tree
	- - - - Square feet per acre	- - - -	Cubic feet per acre	Feet
Fertilized:				
9	1.825	167.25	29.5	0.3
7	2.7	304.76	52.0	.65
10	2.075	253.00	45.3	.525
5	3.8	479.25	76.8	.725
1	3.025	403.75	75.3	.975
Average	2.685	321.60	55.8	.635
Control:				
6	1.325	137.5	15.5	.35
8	1.075	205.75	32.0	.65
4	1.55	208.5	35.8	.475
3	1.75	234.25	38.8	.45
2	1.775	289.25	42.5	.5
Average	1.495	215.05	32.9	.485

[1] Stump growth (below 1 foot) is not included.

Grass production was increased by fertilization:

Treatment and year	Treatment averages	Plot ranges
	(Dry weight (lb/acre))	
Control, 1971	7.4	5.3 - 9.3
Fertilized, 1971	37.2	19.7 - 114.0
Control, 1974	3.7	0 - 12.7
Fertilized, 1974	68.0	18.6 - 183.5

Data for grass production during the 1972 and 1973 growing seasons were lost in the fire mentioned in footnote 1.

Water use from the upper 5 feet of soil in 1974 averaged 6.6 inches for the fertilized plots and ranged from 5.6 to 8.1 inches for individual plots. This use was not significantly greater than the use in the control plots (average 5.6 inches, range 4.2 to 7.9 inches).

Needle length on fertilized trees increased markedly the first season after application (1971), decreased in 1972 and 1974 and even dropped below the prefertilization length in 1973, a very dry year (fig. 4). Needles for the

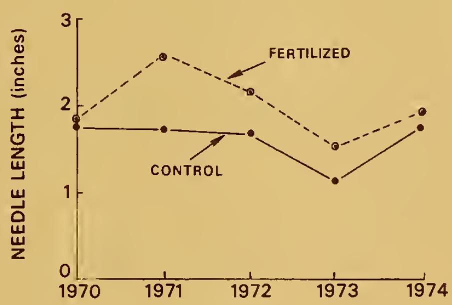

Figure 4.--Needle length for 1 year before and 4 years after treatment. Needles on fertilized trees were significantly longer than needles on control trees at the 1-percent level of probability in 1971 and 1972 and at the 5-percent level in 1973.

trees on the control plot were consistently shorter for 1971, 1972, and 1973. Radial growth of the fertilized trees increased the first season after treatment and continued to increase each succeeding year except for the dry year 1973 (fig. 5). Even in 1973 the difference in radial growth between fertilized and control trees appears slightly greater than in 1972. On the control plot, radial growth appears to be gradually declining.

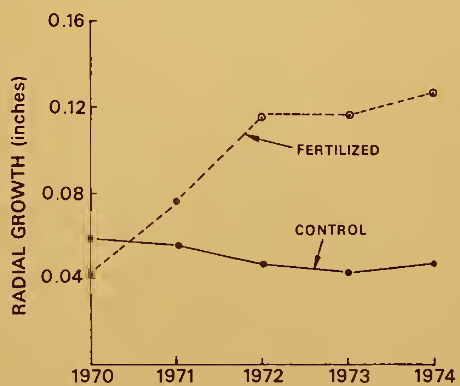

Figure 5.--Radial growth for 1 year before and 4 years after treatment. Differences between the two treatments are significant at the 1-percent level of probability for 1972, 1973, and 1974.

DISCUSSION AND CONCLUSIONS

Although the heavy applications of fertilizer used in the study may never be practical in forest management, the study shows that production of wood and grass in thinned stands can be greatly increased, at least for 4 years, by fertilization. Future remeasurements are needed to determine length of response, but radial growth patterns (fig. 5) indicate that the response will continue beyond 4 years.

Brix and Ebell (1969) found that N-fertilization of 20-year-old Douglas-fir increased leaf area. Later, Brix (1971) reported the N-fertilization increased photosynthetic capacity of new shoots but not older shoots of Douglas-fir even though both chlorophyll and nitrogen concentration increased in older leaves. Total transpiration would also be expected to increase with increased leaf surface area. Further, N-supplied bean plants have been reported to have higher transpiration rates per unit leaf area than N-deficient plants under conditions of high soil moisture (Shimishi 1970).

Patterns of needle length and radial growth (figs. 4 and 5) show that fertilization caused a rapid expansion of needle surface area and photosynthetic capacity the first growing season after treatment. Since lodgepole needles stay on the tree for at least 4 years, the decrease in needle length after 1971 is not necessarily accompanied by a decrease in total needle surface area for the following years. In fact, patterns of radial growth (fig. 5) indicate that the photosynthetic capacity of fertilized lodgepole pine increased every year since treatment except during the dry year 1973. Fertilization did not cause a clear-cut increase in soil water use, but sampling error may have masked real differences. Perhaps total needle surface area and photosynthetic capacity remain constant for a given set of environmental conditions as proposed by Brix (1971). If so, the increased photosynthetic capacity evident from the radial growth pattern suggests increased availability of nutrients for each succeeding year since application except 1973.

The high price and limited supply of fertilizers present a questionable future for fertilization of low-producing stands of lodgepole pine. However, as timber management intensifies, questions about fertilization will continue to arise. Results of this and related studies are necessary to relate soil test values to growth responses, to determine duration of fertilizer response, to determine fertilizer combinations necessary for given growth responses, and to determine the influence of fertilizers on understory vegetation and soil water use.

METRIC CONVERSION FACTORS

1 pound/acre	= 1.121 kilograms/hectare
1 acre	= 0.405 hectare
1 chain	= 20.116 8 meters
1 foot	= 0.304 8 meter
1 inch	= 2.54 centimeters
1 square foot/acre	= 0.229 568 square meter/hectare
1 cubic foot/acre	= 0.069 972 cubic meter/hectare
1 mile	= 1.61 kilometers

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